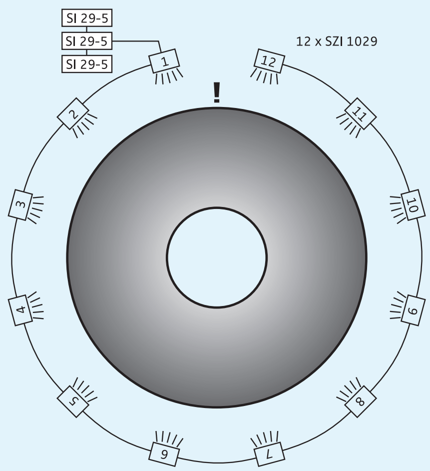
RF Cable Path

IR Audio Transmission Technology | Planning Theory



Cable length between two radiators:	16 m
Cable length between radiator 1 and 8:	176 m
Carrier frequency for channel 12:	575 kHz
Velocity of propagation in the co-axial cable (shortening factor 0.66):	$2{,}00 \cdot 10^{8}\ \mathrm{ms^{-1}}$
Half the wavelength for channel 12:	$\frac{\lambda}{2} = \frac{c}{2 \cdot f} = \frac{2{,}00 \cdot 10^{8}\ \mathrm{ms^{-1}}}{2 \cdot 575\ \mathrm{kHz}} = 174\ \mathrm{m}$

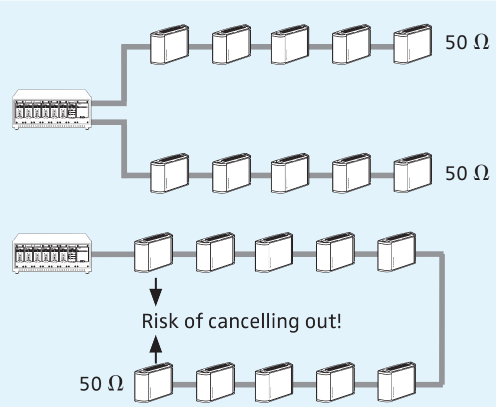
Cancellation between radiators 1 and 12

RF Cable Path

The modulator transmits its output signal via co-axial cables with a characteristic impedance of 50 Ω, such as RG 58 cables. **The total cable length in an RF chain** can amount to several hundred metres without risking a deterioration in transmission quality due to cable losses. The maximum frequency used in IR transmission is in the lower radio frequency range, at 2.8 MHz. Attenuation is thus considerably lower than with radiomicrophone systems which operate at higher frequencies.

In a conductor, waves propagate at finite velocity. The resulting difference in propagation time can lead to cancellations between two radiators. When both radiators transmit the IR information to one receiver, their signals may cancel each other out when you are working with high frequencies and great cable lengths. You should therefore avoid installations where the cable length between two radiators is a multiple of the direct distance between two neighbouring radiators. In multi-channel systems, the cable length between two radiators with overlapping coverage areas should be under 30 m (98.43 ft).

The diagram on the left shows a chamber where the cable length between radiator 1 and radiator 12 is 176 m (577.43 ft). The cable length is about half the wavelength of the RF signal, leading to interference between the two radiators. The exclamation mark shows the area where reception is disturbed.



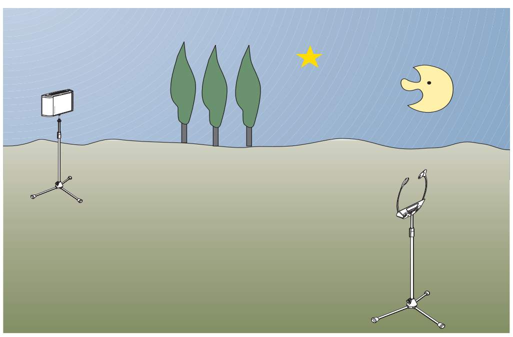
In RF transmission, the output impedance has to be terminated with approximately the same input impedance. If this is not done, reflections may occur at the end of the RF chain and disturb the transmission. So, for reasons of reliability, the end of an RF chain should always be provided with a 50-Ω terminating impedance. Please note that you should not use "T" adaptors in your RF chain as this would halve the terminating impedance.

For large installations you should use both RF outputs of the modulator and create two RF chains. This not only increases reliability but also avoids cancelling out between radiators due to time delay. Please refer to the chapter "Planning Theory" for more information on time delay and cancellations.

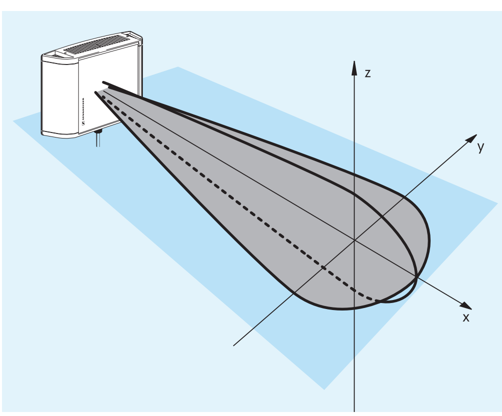
IR Transmission Path

IR Audio Transmission Technology | Planning Theory

Equipment used for the experiments
- CD player with headphone output
- SI 30 modulator/radiator or SZI 30 radiator with suitable modulator
- Suitable receiver



The measurement conditions



Section through the x/y plane

IR Transmission Path

When planning an infra-red transmission system, it is essential to create a reliable IR transmission path. Vital information for planning can be gained from the polar diagrams of the radiators. Even if this seems a bit out of place for a chapter on planning theory: experiments are the best way to illustrate the work with polar diagrams and facilitate the planning of an IR transmission path. Some experiments are described in the following section. If you wish, you can choose those tests which are of interest for your application and do them yourself.

You need a signal source (e.g. a CD player with headphone output), an IR modulator, a radiator and a suitable receiver. It is easiest to work with an SI 30 modulator/radiator. Transmit in stereo – this reduces the coverage area and thus makes the experiments easier. Carry out the tests in darkness and in a free field, i.e. there should be a distance of 40 m (131.23 ft) between the radiator and any objects in the light path. The floor should be dark so as not to influence measurements. A car park or an unused road are ideal for this experiment. Take all measurements in the free field, the illumination being below 100 Lux. This test set-up corresponds to the measurement conditions for polar diagrams.

Now step in front of the radiator. Take care that the receiver's IR diodes point directly at the radiator. Go backwards on the radiator's middle axis until reception becomes disturbed and the RF squelch finally mutes the headphone output. Move to the left and to the right of the middle axis (the X axis in the middle drawing on the left): you can hear which area is still covered and how reception gets bad the further you move away from the axis. In this way, you can "walk along" the radiator's polar diagram, you are testing the coverage area in the XY plane of the radiator.

Now turn the radiator in 90° steps around the X axis. The coverage area should remain the same. This shows you that the radiator – like all Sennheiser IR radiators – emits its light rotationally symmetric to the X axis. Consequently, polar diagrams are a two-dimensional representation of a three-dimensional – lobar – body.

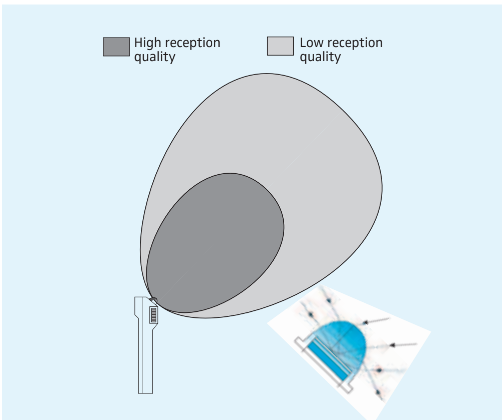
The receiver plane in the polar diagrams is at right angles to the front of the radiator. Now choose a position where reception is good (noise-free). Cover the receiving diode(s) with various materials of differing size. You could for example use A4 size paper, cardboard or your hand. You will notice that IR light is already absorbed by very thin materials such as a sheet of paper. It cannot penetrate opaque materials, with exception of a few types of special plastic material.

Electromagnetic signals, on the other hand, – as for example used for Mikroport transmissions in the 8 m (26.25 ft) band – have longer wavelengths and can overcome obstacles by diffraction. Diffraction does not occur with IR light because its wavelength is in the nanometer range. Now test the radiation angle of the radiator. Walk around the radiator at a distance of 1 m (3.28 ft). The receiver has to be at the height of the radiator and must be pointed directly towards it. Outside the radiation angle of approx. 160°, the signal stops abruptly. In contrast to loudspeakers, for example, which also radiate sound to the rear, IR light only propagates within the radiation angle. Outside this angle, you can only receive a reflected signal, even when you are standing close to the radiator.

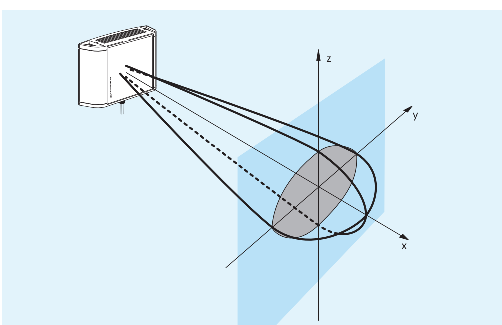
Now stand on the middle axis of the radiator, at a distance at which the signal is already slightly noisy. Turn the IR receiving diode away from the radiator, to the left, the right and upwards and downwards. The signal becomes noisier when the angle is greater, and finally there is no signal at all. You will notice that a receiver exhibits a directional characteristic, just like a radiator. The receiver is more sensitive to light at certain angles, similar to the pick-up pattern of a microphone. In order to make this reception angle as wide as possible – and to focus the incident IR light – each receiver has a converging lens in front of its receiving diode.

IR Transmission Path

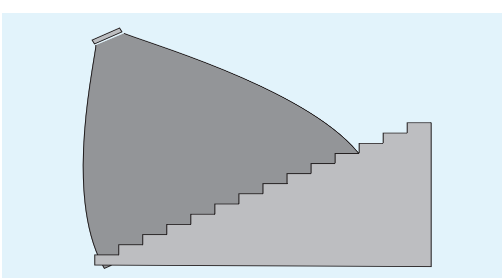
IR Audio Transmission Technology | Planning Theory



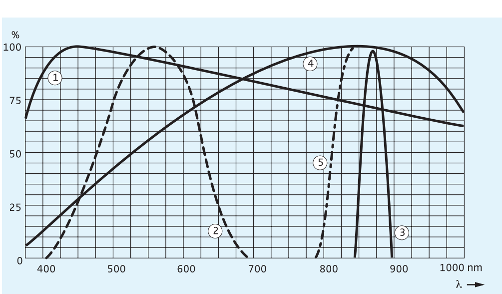
Directional characteristic of a receiver, converging lens



Section through the y/z plane



Sports hall: reception plane parallel to the radiator front



Now we shall take a look at the reception plane parallel to the radiator front. If you mounted the radiator high enough and were able to use a ladder to test different reception points in the YZ plane, you would find that the reception area is circular. When you move away from the radiator, the diameter of this circle increases, the noise gets louder – including on the middle axis – and the circle diameter becomes smaller again. Finally, reception is interrupted.

When you are working in rooms with no reflection, it is especially important to know the directional characteristic of the radiator type you are using. If, for example, you want to cover the stands in a big sports hall with a high and dark ceiling, it is of vital importance to place the radiators correctly. If you choose too small a distance, you will have a good signal-to-noise ratio but the coverage area will be very small. When you use the polar diagram and know the signal-to-noise ratio which would be acceptable for your application, you can determine the largest reception area in the YZ plane.

Choose the height and inclination of the radiators such that the sectional plane through the lobe is as large as possible. Your radiators should for example always radiate into a long room lengthways. Any objects between the radiator and the receiver can absorb a large amount of radiating power – especially when they are close to the radiator. You can avoid such an impairment of transmission quality by positioning the radiators carefully.

The second series of experiments is to be carried out in daylight, and again in the free field, without any influence of reflection or absorption. When the sun shines directly onto the receiving diode, it cannot receive a useful signal. In broad daylight – but with a cloudy sky – disturbance-free operation is possible, but the power of the radiators is reduced to about 60 % of the values that can be attained in the dark. This is due to the fact that daylight also contains IR portions which cause interference. You must therefore use more radiators in rooms with large windows or skylights. If daylight can fall directly onto the receivers, you should darken the room.

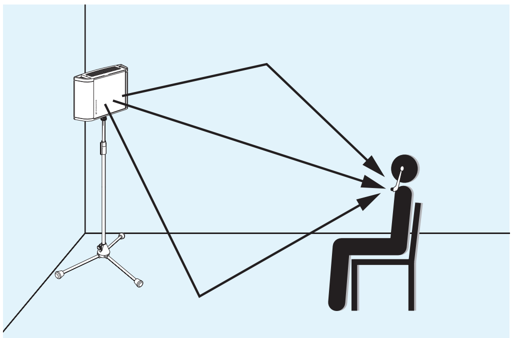
Artificial light contains IR portions too. Low-pressure mercury-vapour lamps, for example, radiate the mercury line at a wavelength of 1014 nm. However, compared to daylight, the light from artificial lighting is usually smaller. For this reason, even bright lights will interfere with an IR transmission only slightly. The coverage area will be slightly reduced. Stage lamps or floodlights used for filming are a different thing altogether. They generate light which is similar to daylight. If, for example, a lectern or a podium table is to be illuminated for a TV take, you should mount high-power radiators close to and pointing directly at the receivers in order to ensure reliable transmission.

High-frequency fluorescent tubes (in compact fluorescent lights for example) have operating frequencies of 30 – 45 kHz. When they are dimmed, this frequency increases to around 70 kHz. The IR portions (mercury line) can interfere with lower narrow-band channels or with the lower wideband channels 95 and 250 kHz, especially channel 1 (95 kHz). If necessary and possible, you should switch to higher channels (≥ ch. 6). The frequencies 2.3 and 2.8 MHz are immune against such influences. Camera flashguns produce cracking sounds in the AF signal when fired. Thus, if the press is very interested in your event, you should plan a photo break.

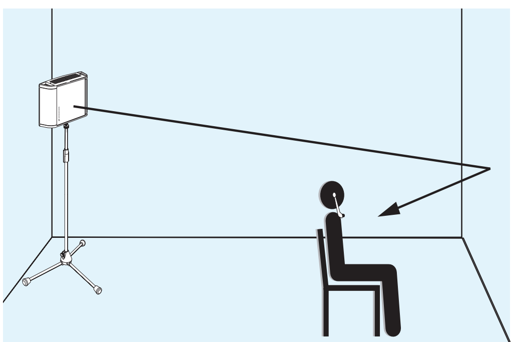
1: Daylight spectrum, 2: sensitivity of the human eye, 3: IR radiator spectrum, 4: sensitivity of IR receiving diode, 5: sensitivity of IR receiving diode with black filter

IR Transmission Path

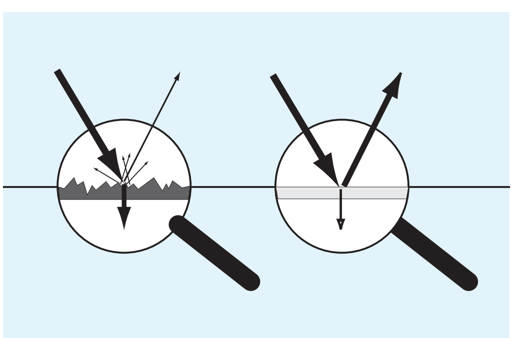
IR Audio Transmission Technology | Planning Theory



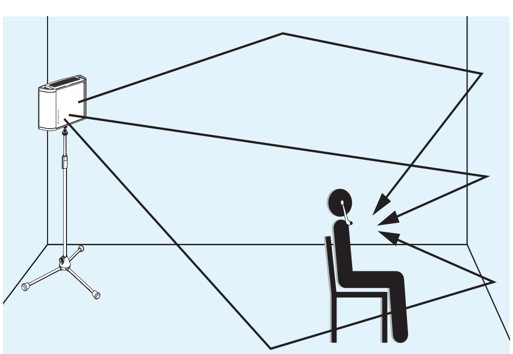
Addition of direct and indirect signals



No direct line of sight, reception by reflection only



Reflection and absorption of different materials



Addition of several reflected signals

Is there a long, bright corridor in your company building? If so, you can use it to carry out the first reflection experiment. Use an SZI 30 to cover the corridor lengthways. Feed it with 12 narrow-band carriers from three SI 29-5 modulators. In a free field, the IR waves can propagate as far as about 10 m on the middle axis of the radiator. If your corridor is longer than 10 m (32.81 ft), you will find that you can still receive the signal outside the normal propagation distance of 10 m (32.81 ft). Depending on the height and width of the corridor and on the type of wall covering, you can achieve a range of up to 15 m (49.21 ft).

This can be explained by the fact that the waves propagate in several ways: you not only receive the direct signal but also signals which are reflected by the floor, the walls and the ceiling. These signals are added at the receiving diode, which allows greater signal ranges than are possible in the free field. In practice, reflection by ceilings is most important. Reflection by walls and floor is in most cases blocked by objects and participants. A low and bright ceiling considerably increases reliability of transmission. A transmission system is most difficult to plan if signals cannot be received directly. You can simulate this case as follows: Return into a free field again and carry out the following test in darkness or in constant (!) daylight.

Get some pieces of various materials with a size of about 1 m x 1 m (3.28 ft x 3.28 ft): woodchip wallpaper, brown cardboard, white laminated hardboard, dark carpet, black cloth, mirror glass... Put on a receiver and turn away from the radiator. Reception will immediately be interrupted. Now hold the different pieces of material in front of you with your arms extended. Align the materials such that the waves radiated by the SI 30/ SZI 30 are reflected onto the receiving diode.

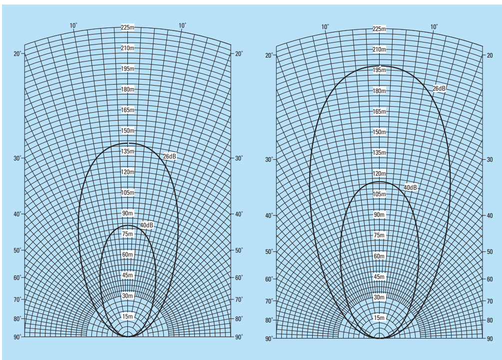
Move away from the receiver on the middle axis and determine the maximum radiator range for the different materials. When you compare them to the maximum range achieved when the receiver is pointing directly at the radiator, you will find that – depending on the material – you attain distances which are 30 % to 70 % of the range for direct reception. When you are using a mirror, the ranges are almost identical (nearly 100 %). Generally speaking, bright and smooth materials reflect the light better than dark, structured ones. In that respect, IR light is very similar to visible light.

If you want to get an idea of the distance which reflected signals can travel, add the radiator–wall distance and the wall–receiver distance. Compare this sum to the range of the radiator. Take the maximum range for the respective radiation angle from the polar diagram and cancel the range corresponding to the number of channels. Now take 30 or 70 % of this value, depending on whether the surfaces are dark or bright.

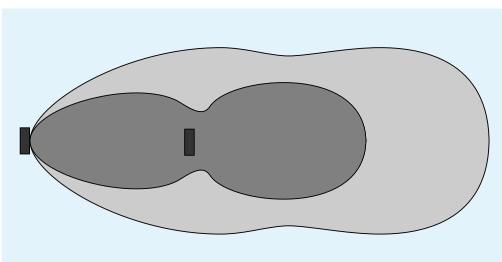
If the calculated range is greater than the total distance between radiator and receiver, only reflected signals will be received. The range achieved with reflected signals can be greater or smaller, depending on room geometry, the addition of different reflected signals (see illustration at the bottom left) and the distance between receiver and reflecting surface.

IR Transmission Path

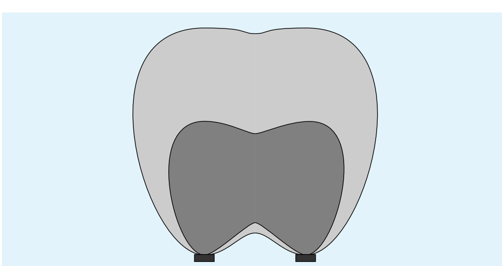
IR Audio Transmission Technology | Planning Theory



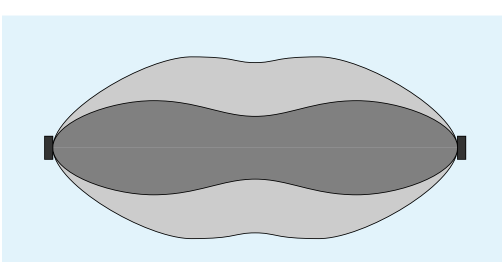
Left: one SZI 1029, right: two SZI 1029 side by side



Two radiators, one placed behind the other



Two radiators side by side but with a distance between them



Two radiators facing each other

If you know the directional characteristic and the polar pattern of your radiator, planning a system with several radiators is easy. The radiators can be positioned as follows:

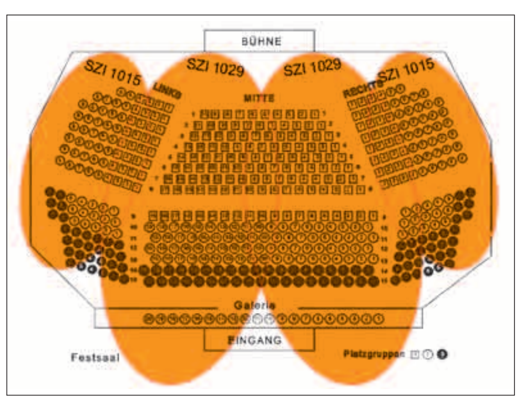
Radiators mounted side by side, no angle: this solution is recommended if the signal is to be received at a great distance along the middle axis of the radiator. If you double the radiating power, the range is increased by $\sqrt{2}$. In contrast to loudspeaker clusters, there is no increase of the power given off due to acoustic coupling or the generation of a coherent signal. This is why decentralised radiator installations are usually more effective.

By placing the **radiators one behind the other**, great distances can be covered. Such a decentralised arrangement with a second radiator front increases transmission reliability. Please note, however, that the receivers should be directed towards the radiators – which may become a problem when all radiators are pointing in the same direction.

Radiators which are mounted at a central high point and at **different angles** can efficiently cover a room. If you want to cover a concentric chamber, for example, a directed central cluster is best. Central installation also saves costs. You will find polar diagrams for this type of arrangement on the product pages for the respective radiators. In high rooms, you must make sure that the radiators are mounted with a slight downward inclination.

If you mount your **radiators side by side** but **with a certain distance between them**, you can uniformly cover a square area. If the receivers are always directed towards the radiators (as would be the case for cinema or theatre applications where the users would watch the stage), you do not need radiators at the back.

Radiators facing one another are the best solution when the direction of the receivers changes, e.g. in multi-purpose halls with varying seat arrangements. Mounting suitable radiators in the four corners of the room ensures reliable reception for any receiver position. When you have installed your system, you can check the reliability of the IR transmission path via the tests described in the chapter "Practical Planning".



Installation of the radiators